

AD-A058 104

MASSACHUSETTS INST OF TECH CAMBRIDGE DEPT OF EARTH A--ETC F/G 17/8  
LASER RANGING AND VERY-LONG-BASELINE INTERFEROMETRY FOR GEODETI--ETC(U)  
FEB 78 I I SHAPIRO, C C COUNSELMAN F19628-75-C-0058

UNCLASSIFIED

AFGL-TR-78-0057

NL

1 OF 1  
AD  
A058 104



END  
DATE  
FILMED  
10-78  
DDC

ADA058104

AD No. \_\_\_\_\_  
DDC FILE COPY

AFGL-TR-78-0057

**LEVEL**

*II*

*(12)*

**LASER RANGING AND VERY-LONG-BASELINE INTERFEROMETRY  
FOR GEODETIC APPLICATIONS**

**Irwin I. Shapiro and C. C. Counselman III**

**Department of Earth and Planetary Sciences  
Massachusetts Institute of Technology  
Cambridge, Massachusetts 02139**

**February 1978**

**Final Report  
1 July 1974 - 30 September 1977**

**Approved for public release; distribution unlimited**

**AIR FORCE GEOPHYSICS LABORATORY  
AIR FORCE SYSTEMS COMMAND  
UNITED STATES AIR FORCE  
HANSCOM AFB, MASSACHUSETTS 01731**



78 08 28 050

Qualified requestors may obtain additional copies from the Defense Documentation Center. All others should apply to the National Technical Information Service.



Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM									
1. REPORT NUMBER <b>AFGL TR-78-0057</b>	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER									
4. TITLE (and Subtitle) <b>Laser Ranging and Very-Long-Baseline Interferometry for Geodetic Applications.</b>		5. TYPE OF REPORT & PERIOD COVERED <b>Final Rept, 1 July 1974-30 Sep 1977</b>									
7. AUTHOR(s) <b>Irwin I. Shapiro C. C. Counselman, III</b>		6. PERFORMING ORG. REPORT NUMBER									
9. PERFORMING ORGANIZATION NAME AND ADDRESS <b>Department of Earth and Planetary Sciences Massachusetts Inst. of Technology Cambridge, MA 02139</b>		8. CONTRACT OR GRANT NUMBER(s) <b>F19628-75-C-0058</b>									
11. CONTROLLING OFFICE NAME AND ADDRESS <b>Air Force Geophysics Laboratory Hanscom AFB, Massachusetts 01731 Monitor/Theodore E. Wirtanen/LWG</b>		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS <b>61102F 2309G101 17G1</b>									
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) <b>TP</b>		12. REPORT DATE <b>February 1978</b>									
		13. NUMBER OF PAGES <b>4</b>									
		15. SECURITY CLASS. (of this report) <b>Unclassified</b>									
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE									
16. DISTRIBUTION STATEMENT (of this Report) <b>Approved for public release; distribution unlimited</b>											
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) <b>404 784</b>											
18. SUPPLEMENTARY NOTES											
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) <table border="0"> <tr> <td>Lunar</td> <td>Lunar libration</td> <td>Onsala Space Observatory</td> </tr> <tr> <td>Laser</td> <td>Very-long-base interferometry</td> <td></td> </tr> <tr> <td>LAGEOS</td> <td>Earth rotation</td> <td></td> </tr> </table>			Lunar	Lunar libration	Onsala Space Observatory	Laser	Very-long-base interferometry		LAGEOS	Earth rotation	
Lunar	Lunar libration	Onsala Space Observatory									
Laser	Very-long-base interferometry										
LAGEOS	Earth rotation										
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) <p>Three distinct tasks were undertaken to advance the application of space techniques to the measurement of geodetic parameters: (i) error analyses were performed to estimate the accuracy with which the locations of satellite tracking stations and the motion of the earth's pole may be determined from laser-ranging observations of the LAGEOS satellite; (ii) a numerical model of the moon's rotation was developed to support the analysis of lunar laser ranging</p>											

observations; and (iii) a very-long-baseline interferometry (VLBI) system was constructed and installed at the Onsala Space Observatory in Sweden for use in a program to monitor the earth's rotation through observations of extragalactic radio sources. The details of this work have been described in three previously published reports.

ADDITIONAL FOR	
WDS	White Section <input checked="" type="checkbox"/>
DOC	Dark Section <input type="checkbox"/>
CHARTHOUSE	<input type="checkbox"/>
JUSTIFICATION	
DISTRIBUTION/AVAILABILITY CODES	
Doc.	APAC and/or SPECIAL
A	

The work done under this contract falls primarily into three distinct categories: (i) error analysis of possible laser ranging to the then-proposed, now-orbiting LAGEOS satellite; (ii) development of a numerical model of the moon's libration; and (iii) the development and deployment of a dual frequency band receiver system for a very-long-baseline interferometer. We discuss our results only briefly below since we give reference to the appropriate reports which present fuller discussions of the individual subjects.

The error analysis of laser ranging to the LAGEOS satellite was undertaken to estimate the accuracy with which both the locations of the laser stations and the motions of the earth's pole could be determined. Five such analyses were performed to simulate the results obtainable with 14 laser stations employed to range to LAGEOS which was assumed to be in a polar, near circular orbit with 10,000 km semimajor axis. The determination of the laser sites typically had standard errors of about 2 cm; the corresponding uncertainties in the other components of the laser site coordinates and in the pole position of the earth typically ranged from about 2 to 10 cm. Further details are given in Reference 1.

In order to best analyze laser ranging observations of the moon to determine relevant geophysical information, we developed our accurate numerical model of the moon's libration. In particular, we developed the equations of motion, and the variational equations, for the moon's rotation in an inertial



coordinate system. The results were compared with a similar model, developed at JPL, that was referenced to a rotating coordinate system. The detailed derivation of the relevant equations and the partial derivatives, and the detailed comparison, is contained in Reference 2.

To measure accurately variations in the rotation of the earth with the technique of very-long-baseline interferometry (VLBI), we developed, constructed, and tested a dual frequency, S- and X-band receiver system similar to that described in Reference 3. This system was deployed at the Onsala Space Observatory in Sweden for initial test in late September, 1977. The test seemed to be successful, but the data analysis could not be completed before the end of this contract. The VLBI receiver system is, of course, intended for future use in a program to monitor the earth's rotation.

#### References

1. Shapiro, I. I., C. C. Counselman III, and R. F. Willson, "Lageos Laser Observations Error Analysis," AFCRL-TR-75-0488, 8 August 1975.
2. Cappallo, R. J., C. C. Counselman III, I. I. Shapiro, and R. W. King, "A Numerical Model of the Moon's Rotation," AFCRL-TR-77-0178, 25 July 1977.
3. Whitney, A. R., A. E. E. Rogers, H. F. Hinteregger, C. A. Knight, J. I. Levine, S. Lippincott, T. A. Clark, I. I. Shapiro, and D. S. Robertson, "A Very-long-baseline Interferometer System for Geodetic Applications," Radio Science 11, 421-432, May 1976.